On-sky speckle nulling through a single-mode fiber with the Keck Planet Imager and Characterizer

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Abstract

The Keck Planet Imager and Characterizer (KPIC) is a series of upgrades for the Keck II Adaptive Optics system and the NIRSPEC spectrograph to enable diffraction-limited, high-resolution (R> 30,000) spectroscopy in the K and L bands. KPIC uses single-mode fibers to couple the adaptive optics system to NIRSPEC, and its sensitivity at small separations is limited by the leakage of stellar light into the fiber. Speckle nulling is a technique that uses a deformable mirror to destructively interfere starlight with itself. We present the first on-sky demonstration of speckle nulling through an optical fiber with KPIC, using NIRSPEC to collect exposures that measure speckle phase for quasi-real-time wavefront control while also serving as science data. We show a decrease in the on-sky stellar coupling by a factor of 2.6 to 2.8 in the targeted spectral order, at a spatial separation of 2 λ/D. This corresponds to an estimated factor of 2.6 to 2.8 decrease in the required exposure time to reach a given SNR, relative to conventional KPIC observations. The performance of speckle nulling is limited by instability in the speckle phase: when the loop is opened, the null-depth degrades by a factor of 2 on the timescale of a single phase measurement. Future work includes exploring gradient-descent methods, which may be faster and thereby able to achieve deeper nulls. In the meantime, the speckle nulling algorithm demonstrated in this work can be used to decrease stellar leakage and improve the signal-to-noise of science observations.

Keywords: speckle nulling, speckle control, onsky, single, mode, fiber, fiber, fed spectrograph

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